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THE MISSION OF SCIENCE IN EDUCATION

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Before determining the method of presenting science in the high school, it is necessary to determine the most valuable contribution of science to education. Perhaps the crux of our differences lies here. If we can agree upon what science should do for us in our work as teachers, we should probably not be very far apart as to the method of securing the result. The variation in method would be no greater than the inevitable and desirable individualism of teachers. If we differ as to the essential contribution of science to education, of course we shall differ as to the methods. The fundamental problem, therefore, is the mission of science in education.

I shall call attention first to some of the results which science is capable of producing, results which are generally acknowledged. It can be used to develop the scientific attitude of mind, which a distinguished theologian recently defined as nothing more than trained common-sense.

This attitude of mind is a spirit of inquiry, which recognizes that we are surrounded by a vast body of established beliefs that need a thorough going-over to distinguish heirloom rubbish from the priceless results of generations of experience. It is also a spirit that demands a close connection between a result and its

claimed cause. Failure to develop this spirit provides the soil in which political demagoguery, destructive charlatanism, and religious vagaries flourish like noxious weeds. It is a spirit that keeps one close to the facts, remembering that a fact is influential only in its own immediate vicinity, and that whole systems of thought and belief lie in a region far beyond the sphere of influence of any facts. In short, it is a spirit that makes for sanity in thought and action, a spirit which is slowly increasing in its influence, but which as yet does not control the majority of citizens. Any subject that can be used to cultivate this spirit is of the greatest practical importance.

Of course the methods introduced by science are now being developed in connection with other subjects, and the same result may be obtained through them; but it still remains true that the scientific spirit just described is more easily and effectively developed in contact with the concrete materials of science.

A stronger claim for science can be made, however, as an essential constituent of all education. It gives a training peculiar to itself, and one that is essential in every well-balanced education. It is this contribution that I wish to emphasize. I shall assume that any peculiar result of science in education must be obtained, not through information in reference to the facts of science, but through contact with the materials of science. However valuable information may be, it can hardly be regarded as a substitute for knowledge. Information is always at least second-hand, while knowledge is first hand. The real educational significance of personal experience, which is a better name for what we call the laboratory method in education, is very commonly overlooked, even by teachers of science.

We were first told that science teaches the laboratory method, the inference being that the content of science is of no particular educational advantage in itself, but is merely useful in teaching a valuable method. Of course this method holds no more relation to science than do algebraic symbols to algebra; they both represent merely useful machinery for getting at the real results.

Then we were told that science cultivates the power and habit of observation. Of course it does, but this is not peculiar to

training in science, for it belongs to any subject in which the laboratory method is used. Then it was claimed that the study of science trains the powers of analysis. This is certainly getting the subject upon higher ground, for the power of analysis is of immense practical importance, but to imagine that analysis is the ultimate purpose of science in education is not to go very much farther than to say that the ultimate purpose is the laboratory method. The latter is the method, the former is but the first step in its application and is by no means peculiar to science.

Beyond analysis lies synthesis, and this certainly represents the ultimate purpose of science. The results of our analysis are as barren as a bank of sand until synthesis lays hold of them; but even synthesis is not peculiar to science. To pass by the incidental and the temporary, and to reach the real and permanent contribution of science to education is to discover that it lies, not in teaching the laboratory method, in developing the power of observation, in cultivating the spirit of analysis, nor even in carrying one to the heights of synthesis, but in the *mental attitude demanded in reaching the synthesis*. In this regard the demands of science are diametrically opposed to those of the humanities, for example, using this loose term to express the great region of literature and its allies. The general effect of the humanities in a scheme of education may be summed up in the single word *appreciation*. They seek to relate the student to what has been said or done by mankind, that his critical sense may be developed, and that he may recognize what is best in human thought and action. To recognize what is best involves a standard of comparison. In most cases this standard is derived and conventional; in rare cases it is original and individual; in no case is it founded on the essential nature of things, in absolute truth, for it is likely to shift. It is the artistic and aesthetic which predominates, not the absolute. The whole process is one of *self-injection* in order to reach the power of *appreciation*. Any education which stops with this result is incomplete, for there is another mental attitude which is a necessary complement before a full-rounded education can be claimed. This complementary mental attitude is developed by a proper study of science.

If the study of nature is conducted so as to cultivate chiefly a sentimental appreciation of natural objects, it is merely more of the same thing. If it is conducted so as to store the memory chiefly with encyclopedic information, it misses the high level of its educational opportunity. If the proper intellectual result of the humanities is *appreciation*, whose processes demand *self-injection*, the proper and distinctive result of the sciences is a *formula*, to obtain which there must be rigid *self-elimination*. Any injection of self into a scientific synthesis vitiates the result. The standard is not a variable and artificial one, developed from the varying tastes of man, but absolute, founded upon eternal truth.

Two such distinct mental attitudes as self-injection and self-elimination must receive attention in education, which cannot be complete without both. They are not contradictory, but complementary. The exclusive cultivation of either one must result in a lopsided development. Persistent self-injection tends to mysticism, a confusion of ideals, or even vagaries, with realities—a prolific cause of all irrational beliefs. Persistent self-elimination narrows the vision to a horizon touched by the senses and clips the wings that would carry us now and then beyond the treadmill of life into a freer air and a wider outlook. The two processes and the two results are so distinct and so complementary that any scheme of education which does not provide for the definite cultivation of these two mental attitudes is in constant danger of resulting in mental distortion.

This seems to be the great and unique mission of science in the education of men and women, and nothing more superficial or temporary should divert us from it. It is men and women we have in mind, and not science, or the various subjects under which it is organized. It is obvious that this mission must reach the greatest number, and therefore its beginnings cannot be deferred to the educational schemes of colleges and universities, where the small minority are in training. This work, therefore, is a high-school problem. We face the question as to the most effective method of accomplishing it.

The problem is peculiarly difficult because it has been much confused by the various standards used to measure the results.

In the main these standards have been too concrete, such as the immediate effect of science upon the earning capacity of the student; the amount of useful information a student may carry into his subsequent life; the number of ordinary phenomena the student can pretend to explain, etc. Too often the higher intellectual standard is lost sight of, the standard of a mind trained to an effective attitude toward all subjects, an attitude that persists when unrelated facts are forgotten.

This confusion becomes worse confounded when incompetent teaching enters into the program, and the obvious results of lack of interest, and lack of any practical or intellectual outcome, are referred to science as a subject rather than to the teacher as an incompetent. From the midst of all this confusion, leading to merited criticism and a babel of opinions, there emerge some facts which seem clear.

Science has become so vast and so complex a subject, and, in addition to this, is so growing a subject, that no teacher can command even its most elementary everyday phases. There was a time when men taught natural science; there is no man who can do this now. If the most obvious facts of science are to be presented truthfully, they must be presented by teachers trained in the various fields of science. If much confusion has arisen from teachers incompetent in some field of science, the amount of confusion that would result if the same group should attempt to teach *all* science must be left to the imagination. Of course, in our everyday experience we face nature as a synthetic affair, but you must remember that synthesis is the last step in progress and is an impossible first step. This means that we must begin by laying hold of single threads and following them, until finally we see them woven into the intricate pattern we call nature; and this is the process that brings appreciation, insight, and intellectual equipment; the process that enables science to achieve its peculiar mission in education.

An illustration may be taken from another synthetic experience, common in large cities, as in Chicago, for example. Almost all the living languages are represented in its population, and yet it would hardly seem rational to teach a child all foreign languages at once,

by picking out the commonest words and phrases from each. The result might be some scrappy information, but to call it education in language would be far from the mark. The real synthetic study of language is philology, based upon some organized knowledge of the different languages.

A division of the materials of science seems necessary, therefore, not only to secure competent teaching, which is a practical reason, but also to secure a point of view that represents the permanent possession which is the essential feature of education. This does not mean organization for the sake of a subject, but for the sake of a pupil; an organization which means a structure that abides, and not inchoate building material.

I sympathize fully with the demand that the materials selected should be more related to the experience of pupils. This is common-sense, and therefore science. I confess that this has been too much lost sight of in our zeal to organize knowledge so that it may be permanent; but the material selected may vary, while the use to which it is put remains the same. The appeal to experience for our material, and the use of this material in organizing a definite body of knowledge, is the combination that will retain all that is vital in our past teaching and admit all that is helpful in the new demands.

Experience teaches us many things, and changes must be made that will satisfy every possible need, without destroying things that are more important. A tree may be made to yield more and better fruit by pruning and grafting, but not by uprooting. My picture of the situation in science teaching is that of a tree, rooted and grounded in all the good that the past has revealed, but reaching out its branches and ever-renewed foliage to the air and the sunshine, and taking into its life the forces of today.

I have met hundreds of students, entering the university from all parts of the country, who have had work in science in high schools, and although the results have been variable, they have been in the main so satisfactory that it is clear to me that science teaching in the high schools has not been a failure. Those who state it is a failure must mean that it has not been as successful as it is capable of being made. I have been interested in tracing the comparative failures to their sources, and invariably I have encountered incompetent teaching as the responsible cause, rather

than the materials of science that have been presented. The majority of cases, however, that have come under my observation are not failures, for they have brought to me a substantial foundation upon which to build, and, what is more important, an aroused interest of their own to build upon the school foundation.

It may be asserted that this evidence is very partial, since it includes only the select few who pass from the high schools into the universities, while the major product of the high schools passes directly into the activities of life. Just how this dissolving crowd can be followed and estimated I am at a loss to imagine. Of course, general impressions are current, which are propagated from no definite source of reliable data. For example, I have heard a business man condemn the whole system of high-school education because of an unhappy experience with one high-school graduate. Nothing is more common than such illogical generalizations, and they may become propagated so extensively as to be regarded finally as a "public demand." The average "public demand" is about the vaguest scientific proposition one ever encounters.

It has been assumed by some that the large majority of high-school students need a type of science instruction entirely different from that which has been given. This assumption is either a response to public demand or a pedagogical abstraction, and in neither case can it rest upon a convincing body of evidence.

Some of the implied criticisms of the present methods are rather difficult to be understood by one who is merely observing the discussion, rather than participating in it. For example, if any science teaching deals with "abstractions" and "generalizations" rather than with concrete material, it is not science teaching. That there should be a certain amount of generalization, based upon observed facts, is obvious, for this is making facts live, which is the pedagogy of the subject. That our science teaching should consist only in explaining to a student what he encounters in his own experience is to limit his life, rather than to enrich it by extending his horizon. There are many things worth knowing which we begin to experience only when our attention is called to them.

Perhaps, however, the best expression of the opinion that the current method of teaching science should be changed entirely is to be found in the recent texts on "general science." I find myself

quite in accord with the motive of what is called "general science," in so far as it voices a growing opinion that high-school students should know more about science in general and tries to meet this opinion with a method. What I cannot agree with is the method, and for reasons indicated in a general way in the preceding part of this paper. A mosaic made up of fragments of information breaks up all natural connections and forbids the development of those ideas which relate and hold facts. As I have said, it seems to be really a substitution of the encyclopedic for the educative. The relations suggested by a mosaic are purely artificial and never can develop a body of *knowledge*, as contrasted with a body of *facts*. With me this is a matter of pedagogy, that is, of the child, and not at all of the sciences as partitioned off into different fields. These sciences can take care of themselves, but we must make them render the best possible service in the education of children.

As one advances through a university, the subjects of science become more and more subdivided, on account of our rapidly growing knowledge. Subdivisions of this kind have no place in elementary instruction, but there are groups of these subjects which are units, so far as education is concerned. It is these natural educational units that must be preserved (and they are not numerous), if science is to do its perfect work in education. I do not understand how an inextricable tangle of these units can be regarded as an education *in* science; certainly it is not an education *by* science.

Of course, when these few natural units are segregated, and perhaps called by names indicating that they are not specialized sciences, then the common experience of life should enter into the choice of illustrative material. We cannot meet the demand for more general acquaintance with science by putting all the sciences into a short course. Such a general acquaintance can be obtained only by extending the time given to science instruction. My program, therefore, would be: enough time for science, so that its natural units may be developed, and also better teaching all along the line.